Soil CO_2 evolution from Korean pine virgin forest at Changbai Mountain[1]

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Abstract The soil CO_2 evolution rate was measured in a virgin Korean pine forest. The results in June showed that the lowest value of evolution rate was 220 mg /(m^2•h) and appeared at 6:00 a.m. The highest value was 460 mg /(m^2•h) at 18:00. The rates of CO_2 evolution were related with soil temperature. On the basis of the constructed regression equation and the monthly average values of temperature, the magnitude of CO_2 evolution from Korean pine forest soil was 10.4 t /hm^2 during a growing season.

Key words: Soil CO_2 evolution, Korean pine forest, Regression equation

Introduction

CO_2 evolution from soil is one of the major processes in global carbon cycling. Increase amount of CO_2 in atmosphere is partly resulted from the disturbance of stabilized vegetation and land used. Some general information for forest ecosystem is available on soil respiration (Schlentner and Cleve 1985). Management practice in forestry clearly has significant effected on the magnitude of soil CO_2 evolution (Ewel *et al.* 1987). Comparison results of soil CO_2 evolution rates at sites in different conditions have been well gotten. But there are few papers about the relative magnitude of biomass of roots, litter and soil organic matter (Hendrickson *et al.* 1984). Site conditions should be selected specifically. The situations on soil CO_2 evolution in ecosystem of Korean pine natural forest is investigated in this study at Changbai Mountain of Northeast China.

Methods

Study site

The study site was selected in forest area with Korean pine (*Pinus koraiensis*) as dominant species. The site is located in the experimental plots adjacent to Forest Ecosystem Research Station in Changbai Mountain (42°24′ N, 128°6′ E) at the elevation of 760m. The stand is a mature Korean pine and broad-leaved tree mixed forest. Major species of broad-leaved trees are *Tilia amurensis, Fraxinus mandshurica, Quercus mongolica, Acer mono* and *Betula platyphylla*. The shrub species mainly consisted of *Acer tegmentosum, Ribes mandshurica, Deutzia amurensis, Corylus mandshurica* and *Lonicera chrysentha*. The herbaceous coverage was low with few species such as *Oxalis acetosella, Lilium dahuricum* and *Urtica angustifolia*. The dark brown forest soil under dense canopy was well for undisturbed thick litter and humus layer.

Measurement of soil CO_2 evolution

Rate of soil CO_2 evolution was measured using an open airflow system connected with a bottomless glass chamber. The chamber was inserted into soil 10 cm deep. The remaining part over soil surface has 1.5 L in volume. The covered surface area was 154m^2 for each of the two chambers. The airflow through chamber by two pumps connected to inlet and outlet started immediately when soil surface was covered. The flow rate at inlet and outlet was the same as 1.2 L per minute, so that the positive or negative air pressure within chamber was avoided. CO_2 from soil respiration was well mixed with the flowing air by a mini-fan set in chamber. Sensors for measuring soil temperature were inserted into the soil of 5 cm deep inside and outside the covering areas. There was no significant difference in soil temperature inside and outside the chamber. When airflow started through chamber after 24h, gas samples were collected from a tube at the outlet every 2h using special bags made of polyene-aluminium film. Each of 3 parallel bags contained 1 L gas. At the same time, the contrast air samples were taken from atmosphere near the inlet tube. CO_2 concentrations of air samples were detected using an infrared gas analyzer soon, after the samples were taken and sent to the laboratory. Soil CO_2 evolution rate was calculated using the equation on CO_2 gas exchange (Sestak *et al.* 1971).

$$C_R = \frac{P_c \cdot F \cdot 10^{-6}}{A} \times \frac{44000}{22.4} \times \frac{273}{273+T} \times \frac{P_1}{P_0}$$

Where:

C_R is rate of CO_2 evolution, mg•m^{-2}•h^{-1};

P_c is difference in CO_2 (ppm) between samples from inlet and outlet;

F is air flow rate through chamber, L•h^{-1};

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A is soil surface area covered, m^2;

T is air temperature during measurement, ℃;

P_1 is atmospheric pressure at measuring site, mb;

P_0 is atmospheric pressure at standard condition.

Results and discussion

Diurnal fluctuation of CO_2 evolution rate

Air samples out of the chambers were collected at 2 h interval from 6:00 to midnight in succession in June and August respectively. At each collection, 6 samples from chamber outlet and 3 samples from ambient atmosphere were taken for detecting CO_2 concentration. The values in Fig. 1 were average values from duplicate samples of two chambers.

At 6:00 in the morning, values both in June and August were comparatively low and were 220 and 280 mg/(m^2•h) respectively. The evolution rate gradually increased during a day. The higher values appeared at 18:00 and reached to 460 or 490 mg/(m^2•h) respectively.

Growing season in this region was known as from April to October and summer time was from June to August. Compared to the value (0.7 g/(m^2•h) by Gordon *et al* (1987) in spruce forest in mid-summer, our results were apparently lower. The highest value in Changbai Mountain area would be expected to appear in July in the region.

Relationship between CO_2 evolution rate and soil temperature

The lowest value of soil temperature was 13 ℃ and appeared at 6:00 and the highest was 16.2 ℃ at 18:00. Diurnal change in CO_2 evolution rate was coincidentally with the change in temperature (Table 1).

Table 1. Values of CO_2 evolution and soil temperature in June

	Time								
	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Soil temperature /℃	13.0	13.8	14.5	15.0	15.7	16.0	16.1	15.2	14.8
CO_2 evolution /mg•m^{-2}•h^{-1}	220	240	290	320	390	440	460	360	300

According to the figures in Table 1, a regression equation was constructed as

$$Y=0.0812e^{0.2476x}$$

Where: Y is CO_2 evolution rate, X is temperature.

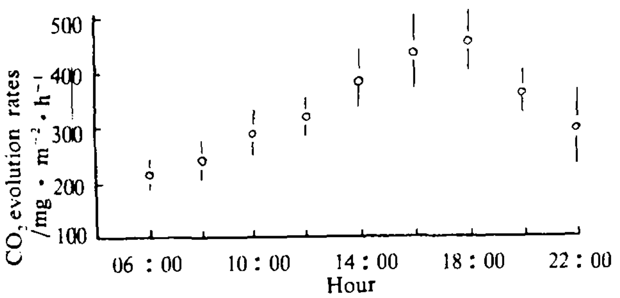

Fig.1. Diurnal fluctuations of CO_2 evolution rate in June

The relationship between evolution rate and soil temperature was found as an exponential form (Fig.2).

As the major factors affecting soil CO_2 evolution, the magnitude of root biomass, organic matter, litter and soil animals, are also important. These factors could affect the of CO_2 evolution in different soil conditions at different sites. Our measurements indicated that the dynamic course of CO_2 evolution for a certain site apparently followed the change of soil temperature with the time course. For estimating the magnitude of soil CO_2 evolution with change of time, it is necessary to understand such dynamic change of different soil CO_2 evolution and to get soil temperature record of the sites.

Estimation of CO_2 evolution from Korean pine forest soil

According to the regression equation on the relationship between CO_2 evolution rate, and the measured monthly average value of soil temperature, we estimated the monthly magnitude of CO_2 evolution in the growing season. The growing season in this region has about 183 d from mid-April to mid-October having detectable soil respiration. From Table 2, a total weight of CO_2 evolution was calculated for 10.4 ton per hectare during the growing season of the year.

Table 2. A calculation of soil CO_2 evolution in growing season

Month	April	May	June	July	August	September	October	Total
Average temperature /℃	4.50	7.80	14.60	16.90	15.70	11.20	5.10	
Evolution rate /mg•m^{-2}•h^{-1}	7	30	290	540	420	120	13	
CO_2 evolution daily /g•m^{-2}•d^{-1}	0.17	0.72	6.96	12.96	10.08	2.88	0.31	
CO_2 evolution monthly /g•m^{-2}•month^{-1}	2.55	22.32	208.80	401.76	312.48	86.40	9.61	1043.9
Total amount /kg •hm^{-2}•a^{-1}								10439

In a report by Ewel *et al.* (1987), an average value of carbon release rate from slash pine (*Pinus elliotii*) plantations in Florida was given as 10.6 t/(hm^2•a). This figure was much higher than our value on the basis of carbon weight. A value of 10.7 t /(hm^2•a) was reported by Edwards and Harris (1977) for tennessee *Liriodendron tulipifera* forest. There was the greater difference for our measurement value on the basis of carbon (2.81 t•hm^{-2}•a^{-1}). And those values might be attributed to the difference of the latitudes and site conditions. The dense canopy and lower soil temperature were found to be the major reasons on our lower value in carbon release in Korean pine forest.

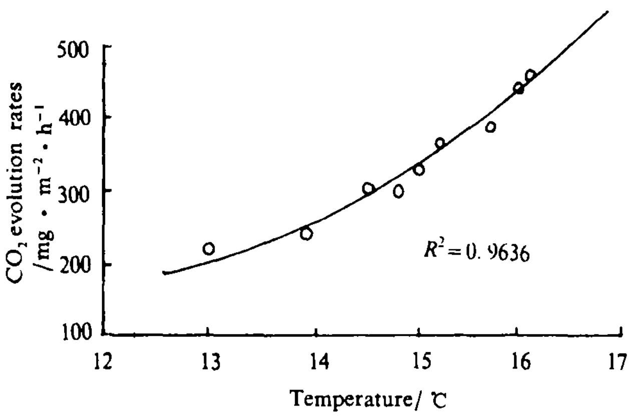

Fig. 2. Relationship between CO_2 evolution rate and soil temperature measured in June under the dense canopy of Korean pine natural forest

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